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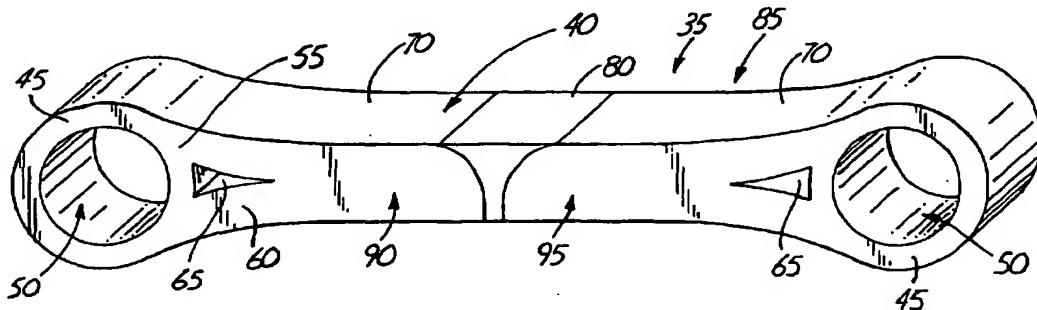
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(54) Title: **MULTI-PIECE EXTRUDED LINK ARM**

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(57) Abstract: Link arms for use in link arm suspension systems are produced through an extrusion and friction stir welding process. Blocks (90, 95) having an eye (50) and a planar body section (70) are formed through extrusion. These sections are then paired together and joined through friction stir welding. The welded joint (80) is positioned in such a location so as to not impact the structural integrity of the completed component. Through this process it is possible to construct link arms having the same structural integrity as previously employed steel link arms while achieving dramatic weight reductions.

## MULTI-PIECE EXTRUDED LINK ARM

### BACKGROUND OF THE INVENTION

#### Field of the Invention

The present invention relates to automotive component parts. More specifically, the 5 present invention relates to the efficient fabrication of automotive parts by first extruding portions thereof, and subsequently joining these various sections to form the completed automotive parts.

#### Description of the Related Art

In any given automobile design, countless diverse components are operatively 10 coupled together to create a sophisticated, high performance machine. Certain components are relatively simple in their design, but can always be improved. Further, the way these parts are fabricated can similarly be improved to provide additional advantages and features. For example, design improvements can continually be made to improve the structural 15 integrity of the product itself. These design improvements may involve how internal component stresses can be better handled, or may implement manufacturing efficiencies. Furthermore, weight reduction is always an important consideration when designing components for vehicles.

Many components have fairly straight forward design criteria based upon their 20 purpose, function, and relationship with other components. One such component is the link arm, or link rod, that is used in vehicle suspension systems. A common link rod design is made up of a steel tube that is welded between a pair of steel eyes. Each eye is fabricated from a steel ring having a wall thickness sufficient to provide the necessary structural 25 reliability. To join these components together the eyes are simply welded to each end of the steel tube. Generally a gas metal arc weld (GMAW) is utilized to achieve the necessary bonding characteristics.

Due to of the shape, design and interconnection of the various components that make 30 up the link arm, a majority of the load stress is concentrated at the weld area. As is obvious, any components which carry loads in a vehicle must easily withstand all loads without the possibility of failure. Naturally, it is very undesirable to have significant loads carried by welded joints due to the possibility of irregularities and inconsistencies in the weld. Furthermore, stress concentration areas are typically created adjacent to a welded joint, which provides another possible source of product failure. More specifically, significant changes in

the geometry and metallurgy at the welded joint create a possibility for product breakage or failure. The location of weld joints is consequently a very important design consideration.

The use of designs which include a significant number of welded components are further undesirable due to problems in maintaining tolerances. More specifically, it is 5 typically difficult to maintain precise tolerances among components when undergoing welding operations. Due to the substantial heat and material stresses that are introduced through the welding process, expansion, bending, bowing and other misalignment concerns are created. In the specific case of the link arm, maintaining exact dimensions between the two eyes becomes difficult during the welding processes. Furthermore, maintaining proper 10 alignment of the eyes and center component is also difficult.

In today's market, vehicles are becoming increasingly modular, thus requiring flexibility among the various components. Naturally, the various components must meet certain physical requirements which are dictated by their application. For example, the link arm is limited to certain lengths and overall dimensions which must possess sufficient 15 structural integrity to withstand certain predetermined load levels applied along various axis. A second vehicle may require similar characteristics from its link arms, but may have slight different length specifications. Unfortunately, two separately fabricated parts are typically necessary to meet this need.

In addition to all of the structural and strength requirements, weight and cost are also 20 continuing concerns. Any reduction in weight of various component parts results in similar weight reductions for the overall vehicle. Naturally, this will result in improved vehicle cost, power requirements, etc. Manufacturing efficiencies also help to reduce overall production costs, and final component part costs as well. Consequently, cost and weight reductions are continual goals when designing any particular component. Therefore, there exists a need to 25 provide an improved link arm meeting the predetermined structural requirements while meeting or exceeding current efficiencies in cost and production.

#### SUMMARY OF THE INVENTION

The present invention seeks to produce a flexible design link arm for use in a vehicle suspension system which has a need for a reduction in weight. Specifically, the present 30 invention reduces the overall weight of the link arm or rod without greatly increasing the cost of the component or the manufacturing process. In achieving these weight and cost savings,

the design of the present invention provides either equal or improved levels of structural reliability.

To achieve the weight reduction desired, the link arm of the present invention is comprised entirely of extruded aluminum (or similar light weight materials); thus achieving a 5 weight reduction of about thirty percent from a similarly sized and shaped traditional steel link arm. However, replacing steel with aluminum creates additional complications. That is, it is generally not practical to join a tubular aluminum rod to a pair of aluminum rings or eyes as was the approach in the steel link arm. This impracticality is due to differing material strengths and weld characteristics, with the welds having less than half of the strength of the 10 base material. As previously discussed, the transition from the small diameter steel tube to the large diameter eye concentrated a majority of the load stress in the weld area. Aluminum components of this configuration would not easily meet all of the necessary requirements of the end product.

To achieve the desired weight reduction by utilizing aluminum, the configuration of 15 the link arm of the present invention is quite distinct from its steel counterparts. Furthermore, to produce such an aluminum link arm in a cost effective manner, a new manufacturing process is utilized.

When viewed from the top (or bottom), the completed aluminum link arm has a generally rectangular configuration. When viewed from the side, a substantial portion of the 20 interior or center section is also rectangular in configuration. Towards each end of the link arm, a transition area begins to taper outward and split, forming a pair of transition arms. An area between the transition arms is hollow. The transition arms terminate in an integrally connected hollow aluminum eye. Again, the entire link arm is fabricated from aluminum achieving a significant reduction in weight. As previously mentioned, other lightweight 25 materials could also be used to fabricate the product, so long as they meet the material requirements outlined below.

To form the aluminum link arm, aluminum is fed through an extrusion press to form components having the desired cross-sectional shape. Several options exist as to the exact 30 number of extruded components required to form a completed link arm. While possible to form the entire link arm in a single extrusion process, this approach is not practical since the link arm is typically about sixteen inches long. At present, it is not cost effective to utilize an extruder capable of producing components with those dimensions due to the lower cost and

improved tolerances of smaller extrusions. Thus, for practical purposes the aluminum link arm of the present invention is formed from at least two extruded components.

In a first embodiment, the extruded component forms one-half of the completed aluminum link arm. As further outlined below, these extruded components are then friction stir welded and subsequent cut to size at a final step. The actual extrusion has a length much larger than the eventual width of a single completed link arm component. To join the extrusions they are first paired side by side and then fed through a friction stir welder. Each single extrusion forms one side of the completed product including the above described eye and a pair of transition arms which lead to a generally rectangular section which terminates in an edge for friction stir welding. By aligning the friction stir welding edge of two such extrusions, the resulting cross-sectional configuration is that of the aluminum link arm.

By joining two extrusions through a stir welding process, no additional material is added (thus preventing additional weight). Further, the stir weld process produces welds that are near base material strength, or two times the strength of gas metal arc welding. The welds are thus more than capable of withstanding the pressures and forces exerted upon a completed link arm. Since the remainder of the link arm is integrally formed through the extrusion process, there is no joint or weld that interconnects the main body of the arm to the eye portions. Therefore, the friction stir weld, with strength near that of the base material, is able to withstand the concentration of stresses which normally occur here.

In a second embodiment, three separate extrusions are used to form a completed link arm. The first two extrusions are similar to those produced in the first embodiment. That is, a hollow eye is produced which is integrally connected to a pair of transition arms that tapers into a somewhat rectangular area that terminates in an edge for friction stir welding. One could simply connect these two extrusions together and produce what amounts to a shortened aluminum link arm. However, in this embodiment a third extrusion is utilized. The third extrusion is a generally rectangular member having a cross-sectional height equal to the cross-sectional height of the other extrusions and a predetermined length. The extruded components are aligned so that the rectangular section is disposed between the two extrusions having hollow eyes. Specifically, the edges are aligned and again are joined through a stir welding process. Thus, by adjusting the dimensions of the rectangular extrusion, the overall length of the link arm can easily be modified.

The combination of extruded component parts and friction stir welding provides a very efficient manufacturing process. The extrusion process is relatively simple and inexpensive. The friction stir welding process is extremely efficient and does not add any weight to the completed product. What results is an aluminum link arm having a weight that 5 is about two-thirds of its steel counterpart while maintaining or exceeding the structural viability of the steel counterpart. Importantly, the costs to produce the aluminum link arm is relatively low and is comparable with that of producing steel link rods due to the elimination of manufacturing processes.

As is known, stir welding occurs by plunging a rotating bit into the metal of two 10 abutted components. The rotating bit is then moved along the seam between these two components. As this occurs, the material is plasticized and essentially forms a bond between the two components. The depth of the bit is selected to correspond to the depth of a seam. In the present invention, the rotating bit passes along the seam created when the two extrusions are aligned side by side. By having the rotating bit travel the entire length, a strong and 15 consistent weld is created along the entire length of the seam. Stir welding operations may be performed on both sides of the component, depending upon the desired weld characteristics. Alternatively, two stir welders may provided which act along both sides of the same seam simultaneously. In either method, the stir weld tool plunges into the two abutted components from the top and the other from the bottom.

Friction stir welding is an enabling technology for the present invention due to the 20 resulting bond. As previously mentioned, an extremely strong weld occurs between the various components. Additionally, friction stir welding does not require excessive amounts of heat, and consequently avoids many disadvantages of classical welding processes. For example, residual stresses and distortion generally caused by the heat utilized in traditional 25 welding processes, is significantly reduced through the use of friction stir welding. Furthermore, the weld strength itself is increased, thus minimizing concerns about weld failures. Friction stir welding also accommodates the production of more precise and easily controlled parts. As mentioned, very little heat input is introduced through the friction stir welding process. Consequently, unnecessary expansion and bending is not inherently 30 created. This allows very tight alignment tolerances to be achieved in the resulting product.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a perspective view of a prior art steel link arm.

Figure 2 is an end view of an aluminum link arm of the present invention.

Figure 3 is a top, partially sectional view of an aluminum link arm of the present invention.

Figure 4 is an end view of a single joint aluminum link arm.

5 Figure 5 is an end view of the two extrusions used to form a single joint aluminum link arm.

Figure 6 is an end view of a double joint aluminum link arm.

10 Figure 7 is an end view of the three extrusions used to form a double joint aluminum link arm along with two alternative rectangular extrusions illustrating how different length double joint aluminum link arms can be formed.

Figure 8 is a perspective view of a single joint aluminum link arm.

Figure 9 is a perspective view of an extrusion for a single joint aluminum link arm.

15 Figure 10 is a perspective view of two extruded sections friction stir welded together, with dashed lines indicating cut lines to cut the welded block into a plurality of single joint aluminum link arms.

Figure 11 is an end, schematic view of a pair of extrusions being stir welded together by a friction stir welder.

Figure 12 is a top view of pair of extrusions being stir welded together.

20 Figure 13 is an end, schematic view of an alternative embodiment wherein the extrusions are simultaneously friction stir welded utilizing two stir weld tools.

#### DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Referring to Figure 1, a representative steel link arm 10 is illustrated. Steel link arm 10 includes a steel tube 15 forming a main body of the component and a pair of steel eyes 20 attached to each end. Steel tube 15 is generally cylindrical in nature and may or may not be 25 hollow depending upon the desired configuration. Steel eyes 20 are each welded to an end of steel tube 15. Each steel eye 20 is a cylindrical member having a hollow interior configured for attachment to other components. In use, a bushing (not shown) is inserted into each eye 20 and steel link arm 10 is then used as a connective component in the link arm suspension system.

30 As mentioned above, steel link arm 10 is manufactured from three separate components that are joined together through a typical welding process. More specifically, steel tube 15 is typically welded to steel eye 20 at weld area 25 by a gas metal arc welding

(GMAW) process. Because the diameter of steel tube 15 is significantly smaller than the width of steel eye 20, force typically applied to link arm 10 when in use creates stress concentrated at weld area 25. With this configuration of a link arm 10, the strength and integrity of the weld between steel tube 15 and each steel eye 20 is absolutely critical.

5 Referring to Figure 2, link arm of the present invention is illustrated and generally referred to as 35. Link arm 35 has a generally rectangular center section 40 forming a main body of the component and at each end of center section 40 is an eye 45 having an hollow eye interior 50. Center section 40 essentially splits into two transition arms, upper transition arm 55 and lower transition arm 60, as it transforms into eye 45. Hollow area 65 is formed  
10 between upper transition arm 55 and lower transition arm 60.

Link arm 35 is partially formed through an extrusion process. While various components or portions are separately identified and enumerated, it is to be understood that link arm 35 (when completed) is essentially a unitary, integral mass of solid aluminum and that the indication of various components or portions thereof is for illustrative purposes only.  
15 As outlined below, the joining or welding of components is minimized to avoid issues related to weld joints.

Hollow area 65 is formed during the extrusion process and simply represents the location within the extrusion where aluminum is not allowed to pass. Hollow area 65 is an optional feature and simply serves to allow for additional weight reductions in that aluminum  
20 need not be present in that location in order to provide the required level of structural integrity to link arm 35. If so desired, additional hollow areas could be located within side surface 75 to achieve further weight reductions so long as the specific levels of structural integrity are maintained.

In use, bushings 53 are placed within eye interior 50 of each eye 45. Subsequently  
25 link arm 35 is used as a connective member in a link arm suspension system. In one embodiment of the invention, link arm 35 is constructed entirely from aluminum resulting in a significant weight reduction when compared to a similarly sized steel link arm 10. When fabricated in aluminum, link arm 35 weighs approximately two-thirds that of the steel link arm 10. It should be noted that while aluminum is the preferred material, other alloys or  
30 extrudable materials could be utilized.

Figure 3 is a top view of link arm 35 and illustrates the generally rectangular overall shape of the component and in particular its upper surface 70. Figures 2 and 3 illustrate how,

in this particular embodiment, link arm 35 is generally symmetrical about a medial bisecting axis 72.

Figures 2 and 3 show aluminum link arm 35 as a single integral component. As previously discussed, link arm 35 is partially manufactured through an extrusion process.

5 Therefore, to form link arm 35 as a single integral unit it would have to be extruded in its completed form as illustrated. As a practical matter, link arm 35 in most applications will be approximately 12 to 25 inches in length. Common extrusion equipment can easily fabricate parts up to approximately 8 inches in length -- one half the typical length of link arm 35. While longer extrusions are possible it becomes difficult to maintain tolerances and their cost  
10 per pound greatly increases. This cost becomes excessive and limits this approach as a viable production option. Therefore, the present invention contemplates forming link arm 35 from at least two separate components.

Figure 4 illustrates a single joint link arm 85 in schematic form, showing how this product is formed from two components. Single joint link arm 85 is formed by coupling a  
15 first extrusion 90 to a second extrusion 95 via a friction stir weld joint 80. While friction stir weld joint 80 is shown as a somewhat U-shaped area, it is understood that this is typically continuous material. Further, the actual configuration or stir weld joint 80 may change depending on various process details. Resulting single joint link arm 85 has the desired length by using two separate shorter components, thus significantly reducing the cost of the  
20 product. When completed, single joint link arm 85 will have a configuration identical to link arm 35, thus those reference numbers are used interchangeably throughout this application.

In order to effectively and efficiently create link arm 35 from multiple components, the components are joined by friction stir welding. The resulting friction stir weld joint 80 has nearly the same strength of the base material and is capable of withstanding the forces  
25 link arm 35 is subjected to. As previously discussed, eye 45 is integral with upper transition arm 55 and lower transition arm 60, thus there is no structural weakness in these areas -- areas which traditionally experience a concentration of stress. The gradual transition of the design geometry provides for this elimination of structural weakness.

Figure 5 is a side view of the two components used to form single joint aluminum link  
30 arm 85 prior to the bonding process. As illustrated, first extrusion 90 terminates in a first extrusion edge 105 and second extrusion 95 terminates in a second extrusion edge 110. First extrusion edge 105 is abutted against second extrusion edge 110. Subsequently a friction stir

welding process is commenced joining the two components together. Further details regarding this friction stir welding process are outlined below. In this embodiment, first extrusion 90 represents one-half of the completed single joint link arm 85 while second extrusion 95 represents the entirety of the other half. Thus, the length of single joint link arm 5 85 is easily controlled by appropriately sizing each extrusion 90, 95. In other words, different sized extrusions 90, 95 can easily be manufactured to create completed single joint link arm 35 of various lengths. Additionally, variations in each component can be easily accommodated. While the two extrusions, 90 and 95, are shown to be substantially similar in their cross-section, this is not necessarily a requirement. It is easily understood that non-10 symmetrical link rods can easily be manufactured using the principles outlined above.

The present design of link arm 35 can easily be modified to create a variety of different sizes and lengths. When it is desired to produce a variety of link arms having different lengths, it may be more efficient to produce the double joint link arm 115 as illustrated in Figure 6. Double joint link arm 115 is formed from three separate components -15 - a first extrusion 90, a rectangular extrusion 120, and a second extrusion 95. To create the completed product rectangular extrusion 120 is inserted between first extrusion 90 and second extrusion 95. These components are subsequently joined to one another through the friction stir welding process producing a first friction stir weld joint 125 and a second friction stir weld joint 130. In this design, it is readily apparent that varying the length of rectangular 20 extrusion 120 will result in the production of double joint aluminum link arms 115 having different lengths. It is also readily apparent that using first and second extrusion 90, 95 of the embodiment in Figure 4 with the rectangular extrusion 120 is possible and can result in an even longer double joint link arms 115.

Once again, first friction stir weld joint 125 and second friction stir weld joint 130 are 25 shown as somewhat U-shaped areas of double joint link arm 115. It is again understood that this is for illustrative purposes only as the resulting joint is made up of substantially continuous material. Again, various other configurations are possible, depending upon the various processes utilized to create first friction stir weld joint 125 and second friction stir weld joint 130.

30 Figure 7 illustrates double joint aluminum link arm 115 prior to the friction stir welding process. That is, first extrusion 90, rectangular extrusion 120 and second extrusion 95 are still separate from one another. First alternative rectangular extrusion 140 and second

alternative rectangular extrusion 145 are provided to illustrate how providing different lengths of the medial section will result in the desired overall dimensions of the completed product. Once again, the location and quality of the friction stir weld joints 125, 130 are such that the overall construction of double joint aluminum link arm 115 is structurally sound.

5 To form double joint aluminum link arm 115, first extrusion edge 105 is aligned with one rectangular extrusion edge 135 while second extrusion edge 110 is lined with the opposite rectangular extrusion edge 135. The components subsequently passed through a friction stir welder to form a first and second friction stir weld joint 125, 130. Ideally, both friction stir weld joints 125, 130 can be formed simultaneously. Alternatively, the joints can  
10 be formed one at a time.

Referring to Figure 8, a perspective view of a single joint link arm 85 is presented. From this view it becomes apparent how connecting arm 40 is formed from portions of both first extrusion 90 to second extrusion 95. By joining the edges of the first and second extrusions 90, 95 a generally rectangular connecting arm 40 is formed. This presents a seam  
15 between two surfaces which can then be optimized for the friction stir welding process. By optimizing the extrusion edges for the friction stir welding process, connecting arm 40 can be thinner with respect to the widest portion of eye 45 due to the improved weld integrity. In other words, upper and lower transition arms 55, 60 are allowed to taper from connection arm  
40 to match the dimensions of eye 45. This is opposed to requiring that side surface 75 have  
20 a more rectangular configuration equivalent to the widest portion of eye 45 which would in turn require more material and increase the overall weight of the link arm 85.

To manufacture link arm 35, aluminum is fed through an extrusion press to produce a relatively large block or extrusion 150 as illustrated in Figure 9. As viewed from the side surface 75, extrusion 150 is equivalent in size and shape to either first or second extrusion 90, 95. However, extrusion 150 has a much larger length as represented by dimension L. The exact length selected will vary depending on the capabilities of the handling equipment being employed to manufacture completed aluminum link arms 35. Extrusion 150 includes extrusion edge to be friction stir welded 155 on a side opposite of eye 45.

Referring to Figure 10, it can be seen that two extrusions 150 are joined side by side.  
30 More specifically, extruded edge 155 of a first extrusion 150 is abutted against extrusion edge 155 of a second extrusion 150. A friction stir weld 80 is then produced where extrusion edges 155 abut one another. Since each of the extrusions 150 are identical, when so welded

the width W of joined block 160 is equivalent so the length of extrusion 150. Cut lines 165 illustrate where joined block 160 will be cut by cutting saw 170 (schematically illustrated) to form a plurality of single joint aluminum link arms 85. Of course, the cutting process would be the same to produce a plurality of double joint aluminum link arms 115.

5       Cutting saw 170 is simply schematically illustrated. In practice, cutting saw 170 would be an industrial, high-speed production cutting saw preferably with a large circular blade (e.g. having a 22 inch diameter and 60 carbide teeth). Alternatively, other cutting methods could be used, such as an industrial band saw, or laser cutting. After each section is  
10      cut from joined block 160, the various surfaces are deburred. Subsequently a bushing 53 is inserted into each eye 45. Various types of bushings may be applied. For example, metal  
sleeved bushings can be utilized. Eye 45 may need to be reamed so that hollow area 65 is set  
to the correct dimensions. This is necessary because of the tight tolerances required for such  
metal sleeve bushings, which are beyond the capabilities of the extrusion process. If non-  
sleeve bushings are to be employed, the tolerances of hollow area 65 can be adequately  
15      achieved through the extrusion process.

Referring to Figures 11 and 12, the stir welding process of the present invention is illustrated. As previously explained, to form the completed component the extrusion edges 155 of two opposed extrusion blocks 150 are first aligned against one another. The gap between each extrusion edge 155 is referred to as weld seam 100. In practice, first extrusion  
20      90 is abutted against second extrusion 95 and weld seam 100 is a minuscule space between  
opposing extrusion edges 155.

As previously discussed, friction stir welding is accomplished by utilizing a friction stir welder 175 which includes a friction stir welding bit or tool 180. Welding bit 180 includes a tip 182 which extends from a collar portion 177. In practice, tip 182 is allowed to  
25      extend completely into the work pieces, while collar 177 is simply positioned at or slightly  
above the adjacent surfaces of the materials being welded. Tip 182 extends into a substantial  
portion of the weld joint, thus sufficiently plasticizing material in that area.

Once so aligned friction stir welder 175 is activated causing the respective welding tool 180 to rotate at a rapid rate. As the welding tool 180 pass along weld seam 100 their  
30      rotation plasticizes the aluminum and creates a pool of revolving plasticized material. As  
more clearly shown in Figure 12, friction stir welder 175 (in addition to rotating) moves  
along a direction of travel as indicated by the arrow. As this occurs the plasticized material

around welding tool 180 is moved behind the tool 180. The material then solidifies forming a solid bond or stir weld joint 80.

The friction stir welding process does not introduce any consumables into the weld joint 80. Thus, the weight of the final product is dependent entirely upon the weight of the 5 extruded aluminum.

Most importantly, the friction stir welding process does not melt the aluminum to produce a quality joint. Thus, the weld joint 80 is formed with a minimal amount of distortion. This results in a better quality bond between the two components. In comparison, 10 traditional welding processes subject the material to extreme amounts of heat which change and ultimately weaken the structural integrity of the aluminum. Thus, the friction stir welding process is critical to the formation and fabrication of aluminum link arms 35. Additionally, this allows very precise dimensional tolerances to be maintained.

While a single stir welder can be employed in the known way, to bond first extrusion 90 to second extrusion 95 a dual stir welder configuration may be used. As more specifically 15 shown in figure 13, a first friction stir welder 175 is orientated above first and second extrusions 90, 95 so that a rotatable welding tool or bit 180 protruding from first friction stir welder 175 is aligned with weld seam 100. Welding tool 180 is selected so that when it is plunged into the aluminum to the maximum depth allowed by collar 177, welding tool 180 will extend to a depth of approximately one-half that of first and second extrusion 90, 95. 20 Similarly, a second friction stir welder 185 is orientated underneath first and second extrusion 90, 95 with a rotatable welding bit 190 orientated with weld seam 100. Once again, the size of the second welding tool 190 is selected so that when plunged into the aluminum to the maximum depth allowed by collar 187, welding tool 190 will extend approximately one-half the distance into first and second extrusion 90, 95.

25 Those skilled in the art will further appreciate that the present invention may be embodied in other specific forms without departing from the spirit or central attributes thereof. In that the foregoing description of the present invention discloses only exemplary embodiments thereof, it is to be understood that other variations are contemplated as being within the scope of the present invention. Accordingly, the present invention is not limited in 30 the particular embodiments which have been described in detail therein. Rather, reference should be made to the appended claims as indicative of the scope and content of the present invention.

## CLAIMS

What is claimed?

1. A method of fabricating an aluminum link arm for use in a link arm suspension system, comprising:

extruding a first unitary aluminum block having a first end and a second end, wherein  
5 the first end includes a eye section with a hollow eye interior and the second end includes a welding edge;

extruding a second unitary aluminum block having a first end and a second end, wherein the first end includes a eye section with a hollow eye interior and the second end includes a welding edge;

10 placing the welding edge of the first aluminum block adjacent to the welding edge of the second aluminum block to form a seam therebetween; and joining the first aluminum block to the second aluminum block to form a joined block by moving a first rotating bit of a first friction stir welder along the seam so that a stir welded joint is formed.

15 2. The method of claim 1, further comprising:

cutting through the joined block in a direction generally perpendicular to the stir welded joint so that the cut separates a portion of the joined block having a predetermined width approximately equal to the desired width of the aluminum link arm.

20 3. The method of claim 2, further comprising:

inserting a first sleeved bushing into the hollow eye interior of the first unitary aluminum block and a second sleeved bushing into the hollow eye interior of the second unitary aluminum block.

4. The method of claim 1, wherein the first unitary aluminum block further includes a hollow area between the eye section and the welding edge and the second unitary aluminum block further includes a hollow area between the eye section and the welding edge.

25 5. The method of claim 1, wherein joining the first aluminum block to the second aluminum block, further comprises:

placing a second friction stir welder adjacent the seam, so that the first friction stir welder and the second friction stir welder are positioned on opposite sides of the first aluminum block from one another; and

5 moving a second rotating bit of the second friction stir welder along the seam, simultaneously with the bit of the first friction stir welder so that a stir welded joint is formed.

6. An aluminum link arm made by the process of claim 1.

7. A method of fabricating an aluminum link arm for use in a link arm suspension system, comprising:

10 extruding a first unitary aluminum block having a first end and a second end, wherein the first end includes a eye section with a hollow eye interior and the second end includes a welding edge;

extruding a second unitary aluminum block having a first end and a second end, wherein the first end includes a eye section with a hollow eye interior and the 15 second end includes a welding edge;

extruding a planar block section having a first edge and a second edge;

placing the welding edge of the first aluminum block adjacent to the first welding edge of the planar block section to form a first seam therebetween;

placing the welding edge of the second aluminum block adjacent to the second welding edge of the planar block section to form a second seam therebetween; and

20 joining the first aluminum block to the planar block section by moving a rotating bit of a friction stir welder along the first friction stir welding seam so that a first stir welded joint is formed; and

25 joining the second aluminum block to the planar block section and the first aluminum block to form a joined block by moving the rotating bit of the friction stir welder along the second friction stir welding seam so that a second stir welded joint is formed.

8. The method of claim 7, further comprising:

cutting through the joined block in a direction generally perpendicular to the first and second stir welded joints so that the cut separates a portion of the joined block having a predetermined width approximately equal to the desired width of the aluminum link arm.

5 9. The method of claim 8, further comprising:

inserting a first bushing into the hollow eye interior of the first unitary aluminum block and a second bushing into the hollow eye interior of the second unitary aluminum block.

10. 10. The method of claim 7, wherein the first unitary aluminum block further includes a hollow area between the eye section and the welding edge and the second unitary aluminum block further includes a hollow area between the eye section and the welding.

11. 11. The method of claim 7, wherein joining the first aluminum block to the planar block, further comprises:

15 placing a second friction stir welder adjacent the first seam, so that the first friction stir welder and the second friction stir welder are positioned on opposite sides of the planar block from one another; and

moving a second rotating bit of the second friction stir welder along the first seam, simultaneously with the bit of the first friction stir welder so that a stir welded joint is formed.

20 12. The method of claim 10, wherein joining the second aluminum block to the planar block, further comprises:

placing the second friction stir welder adjacent the second seam, so that the first friction stir welder and the second friction stir welder are positioned on opposite sides of the planar block from one another; and

25 moving the second rotating bit of the second friction stir welder along the second seam, simultaneously with the bit of the first friction stir welder so that a stir welded joint is formed.

13. An aluminum link arm made by the process of claim 7.

14. An aluminum link arm for use in a link arm suspension system, comprising:
  - a first integral extruded aluminum section having a first eye portion defining a first hollow eye interior, a first substantially rectangular main body portion, and a first hollow area located adjacent to the first eye portion; and
  - 5 a second integral extruded aluminum section having a second eye portion defining a second hollow eye interior, a second substantially rectangular main body portion, and a second hollow area located adjacent to the second eye portion, wherein the first main body portion of the first integral extruded aluminum section is joined to the second main body portion of the second integral extruded aluminum section by a friction stir weld.
- 10
15. The aluminum link arm of claim 13, further comprising:
  - a first arcuate upper transition arm joining the first main body portion to an upper portion of the first eye portion;
  - a first arcuate lower transition arm joining the first main body portion to a lower portion of the first eye portion;
  - 15 a second arcuate upper transition arm joining the second main body portion to an upper portion of the second eye portion; and
  - a second arcuate lower transition arm joining the second main body portion to a lower portion of the second eye portion.
- 20
16. An aluminum link arm for use in a link arm suspension system, comprising:
  - a first integral extruded aluminum section having a first eye portion defining a first hollow eye interior, a first substantially rectangular main body portion, and a first hollow area located adjacent to the first eye portion;
  - a generally rectangular extruded aluminum section having a first end and a second end;
  - 25 a second integral extruded aluminum section having a second eye portion defining a second hollow eye interior, a second substantially rectangular main body portion, and a second hollow area located adjacent to the second eye portion, wherein the first main body portion of the first integral extruded aluminum section is joined to the first end of the rectangular extruded aluminum section by a first friction stir weld and the second main body portion of the second
- 30

integral extruded aluminum section is joined to the second end of the rectangular extruded aluminum section by a second friction stir weld.

17. The aluminum link arm of claim 15, further comprising:
  - a first arcuate upper transition arm joining the first main body portion to an upper portion of the first eye portion;
  - a first arcuate lower transition arm joining the first main body portion to a lower portion of the first eye portion;
  - a second arcuate upper transition arm joining the second main body portion to an upper portion of the second eye portion; and
  - 10 a second arcuate lower transition arm joining the second main body portion to a lower portion of the second eye portion.

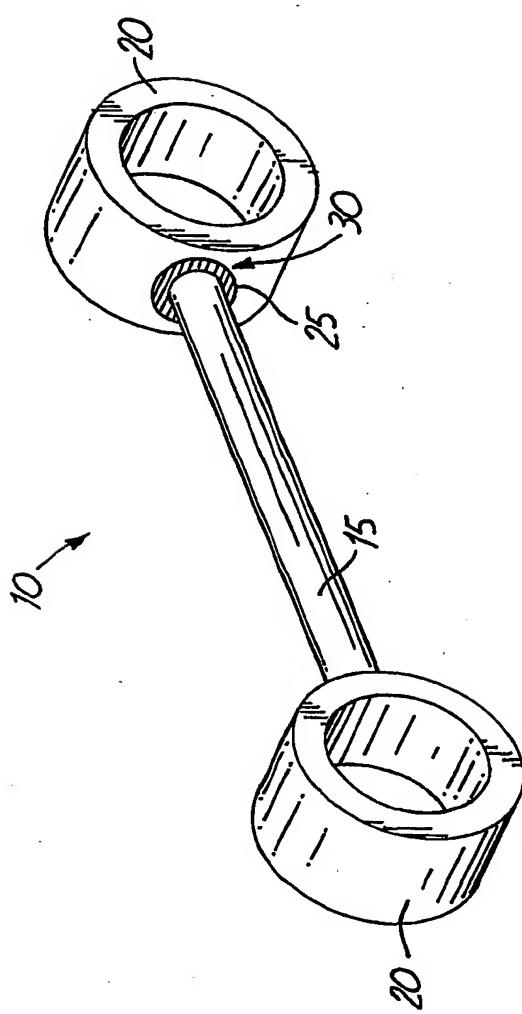
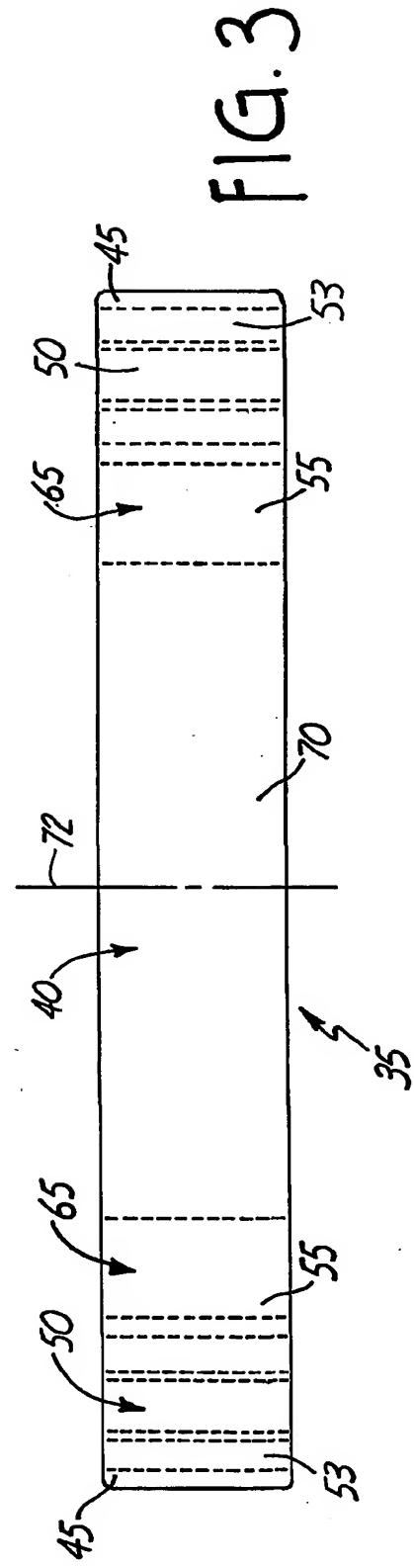
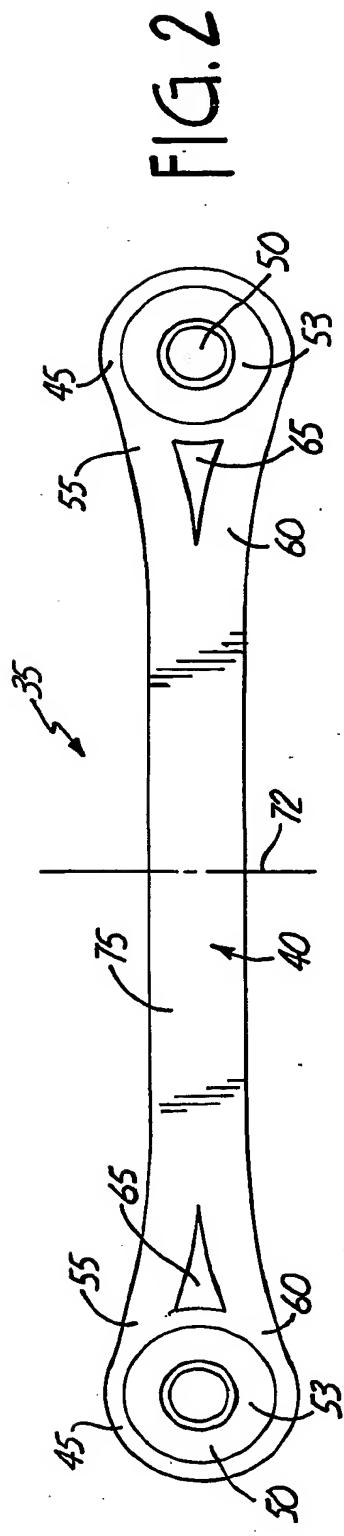


FIG. 1

PRIOR ART



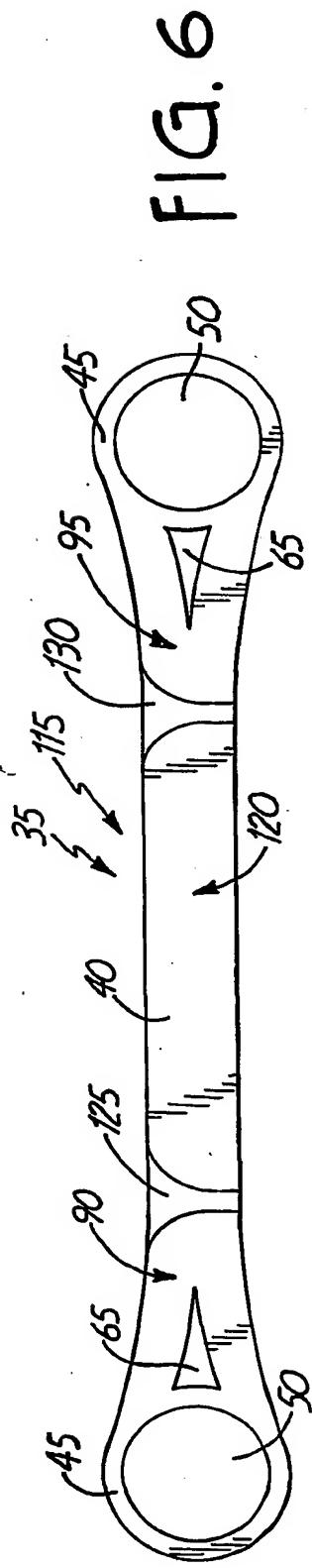
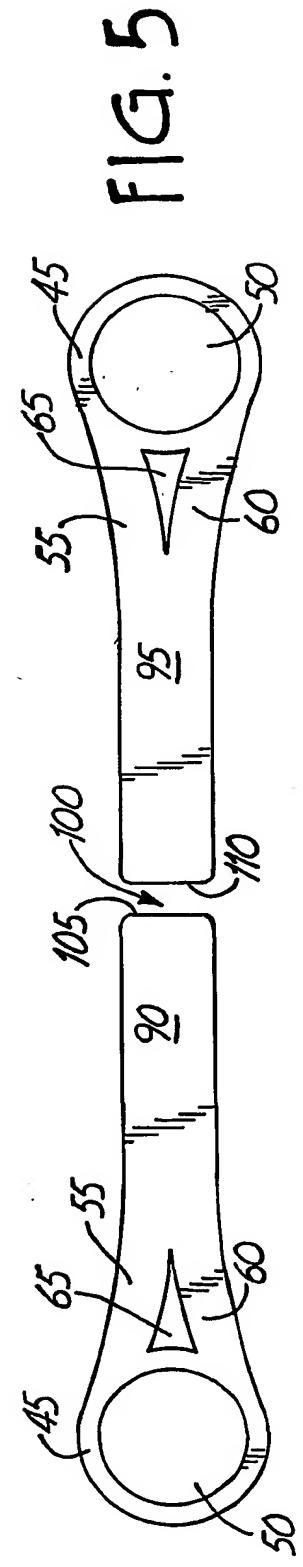
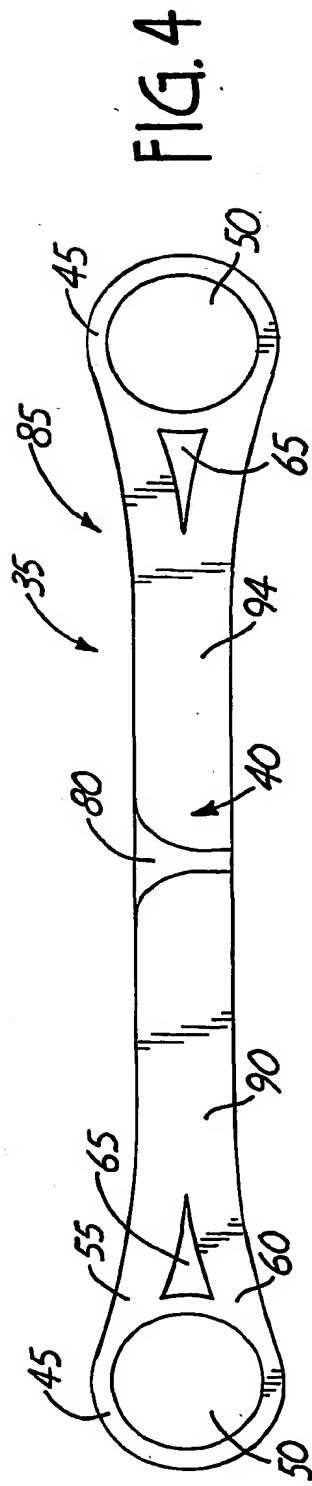


FIG. 7

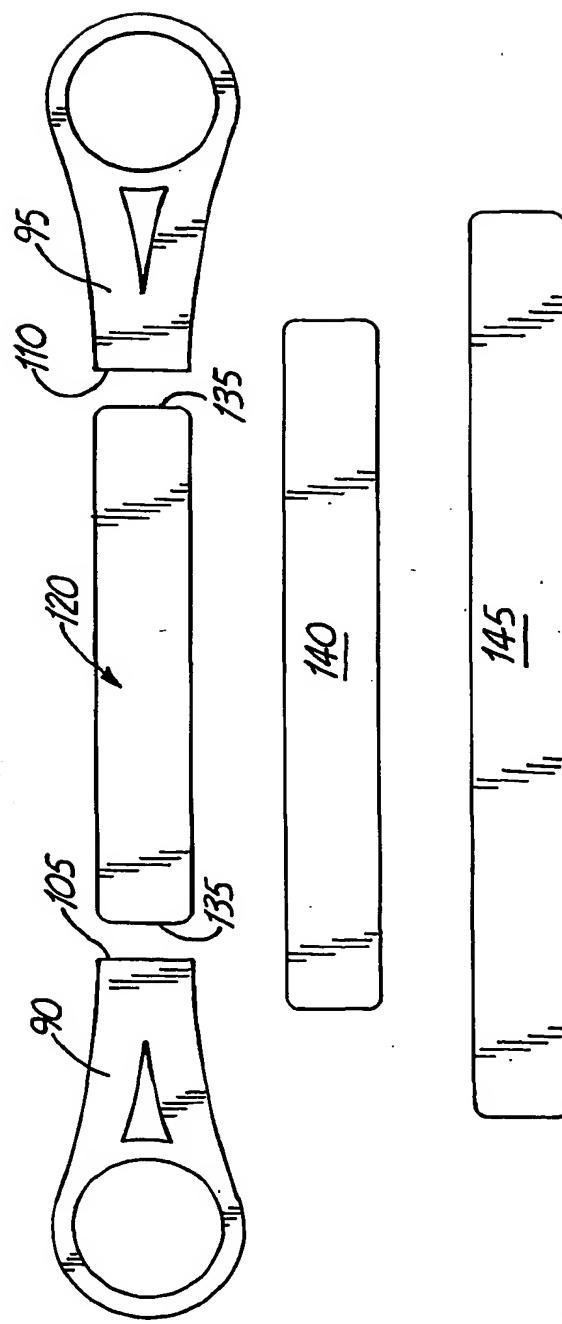


FIG. 8

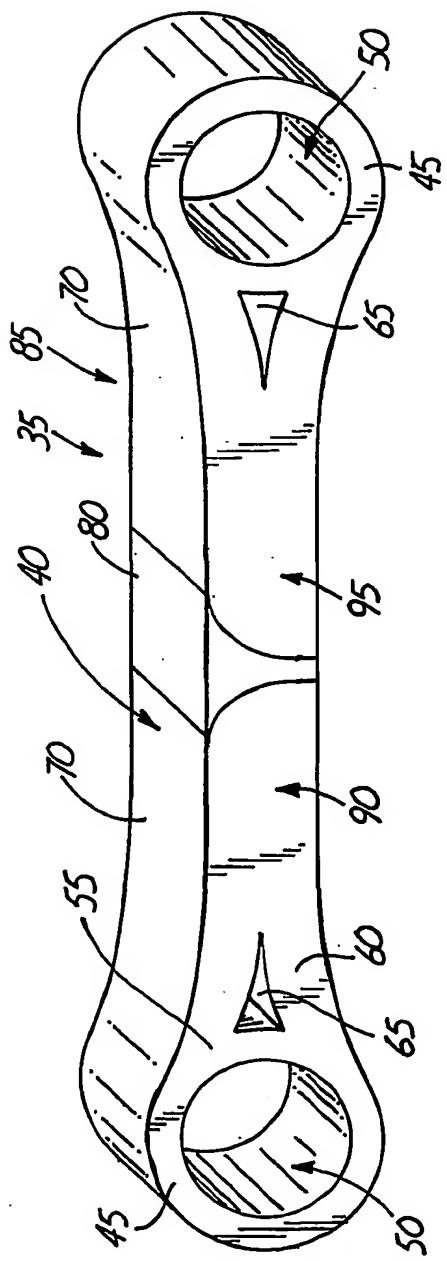


FIG. 9

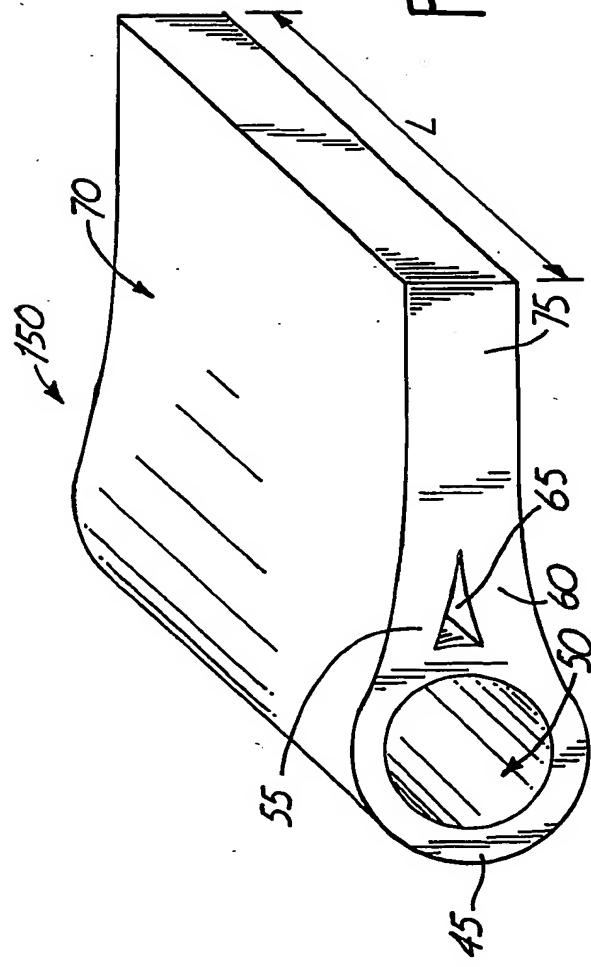


FIG. 10

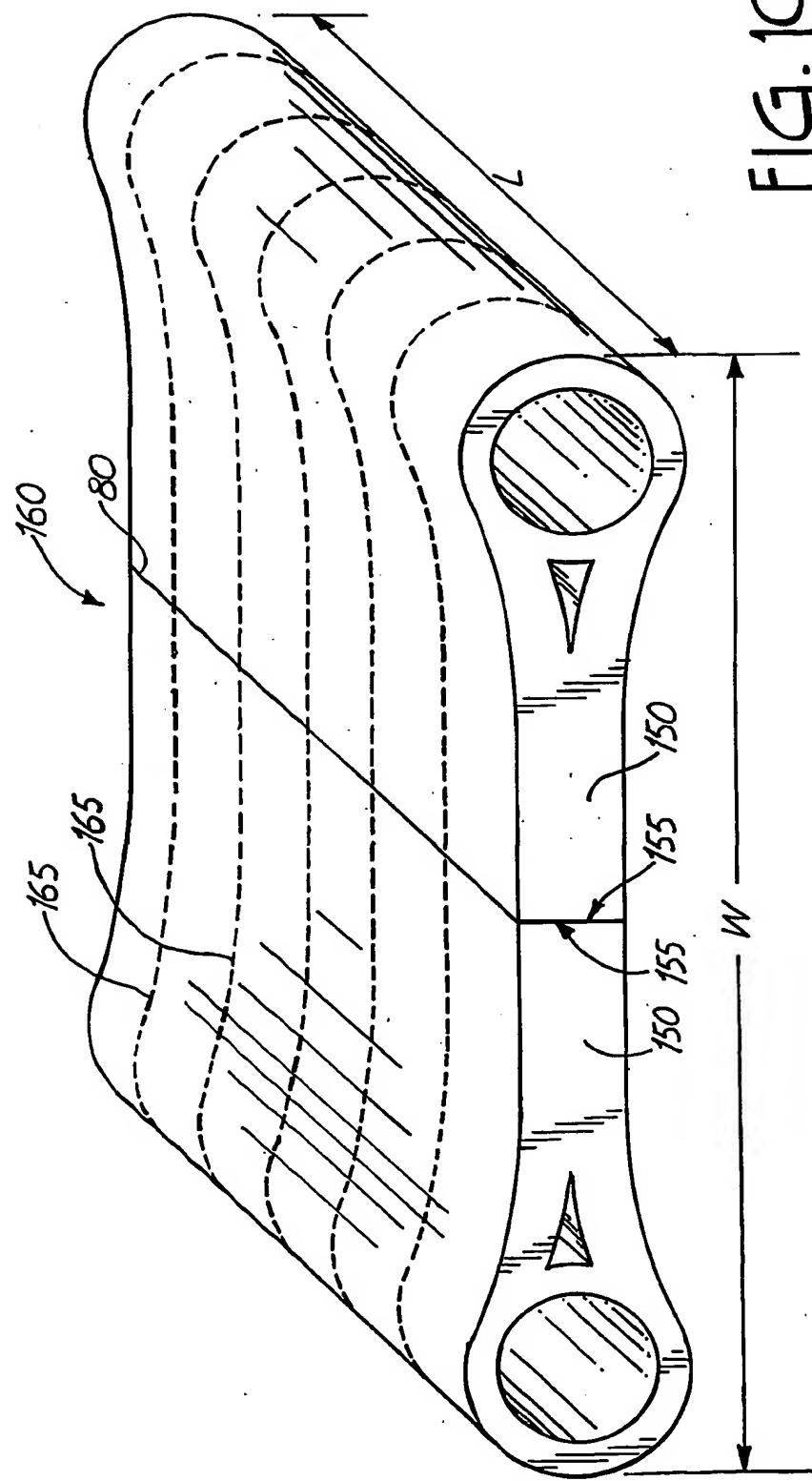


FIG. 11

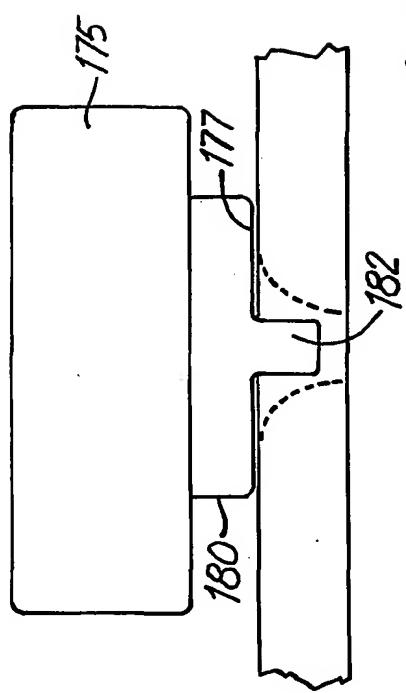


FIG. 12

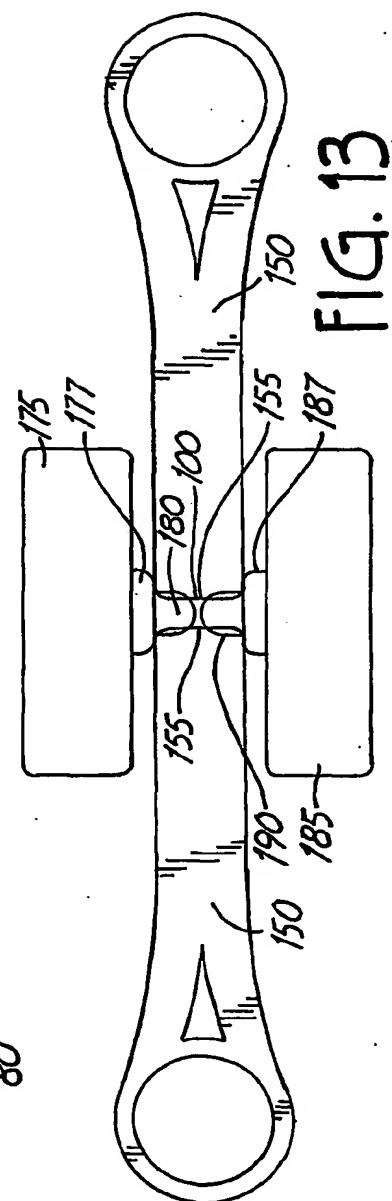
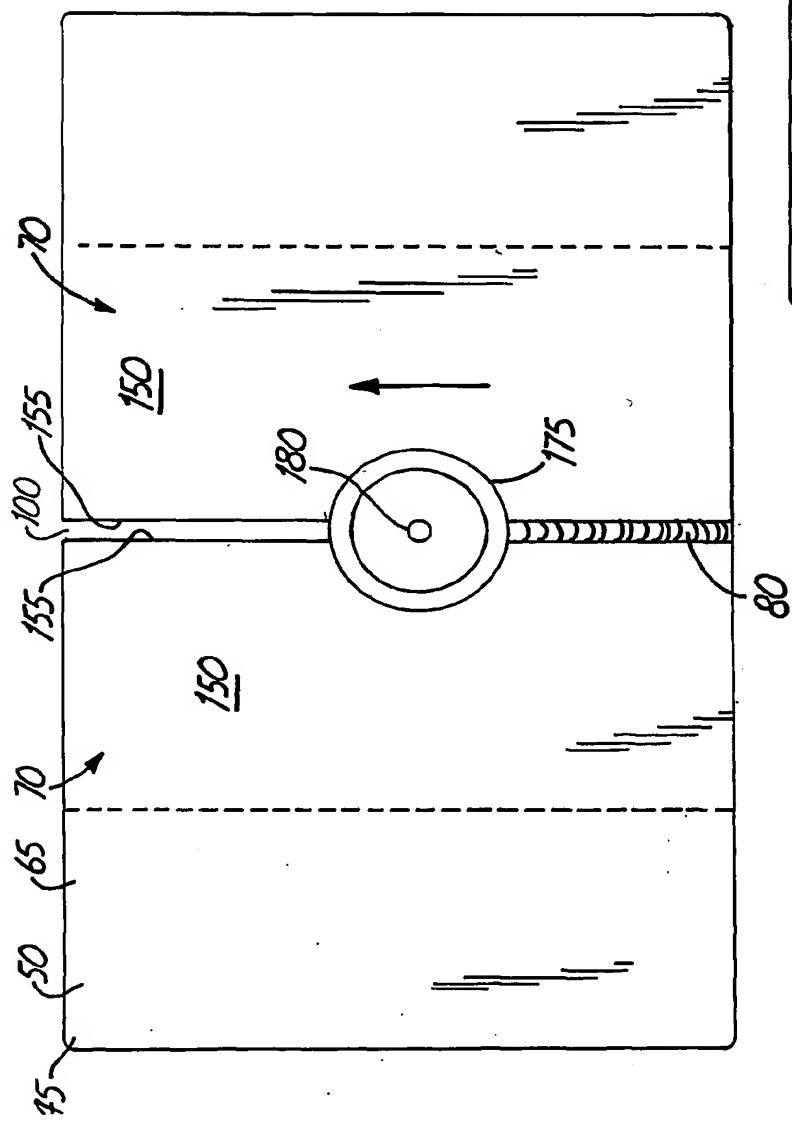


FIG. 13

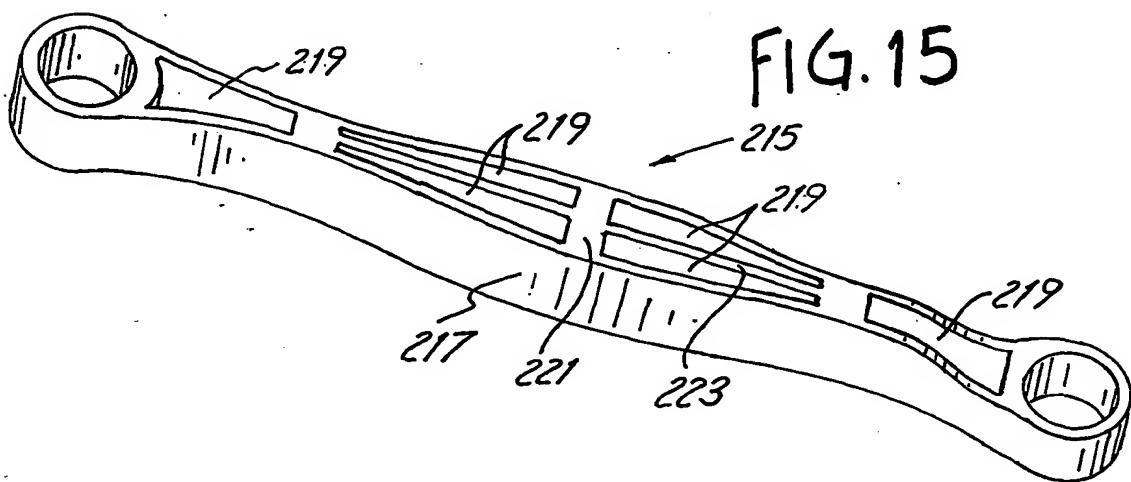
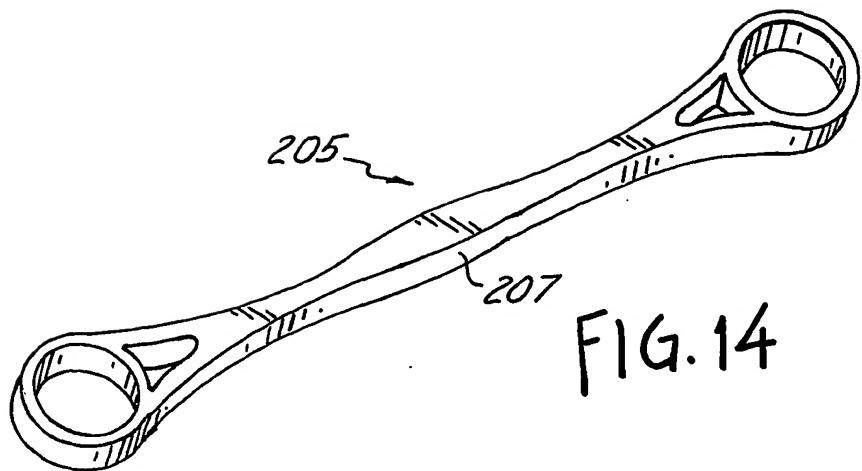


FIG. 16

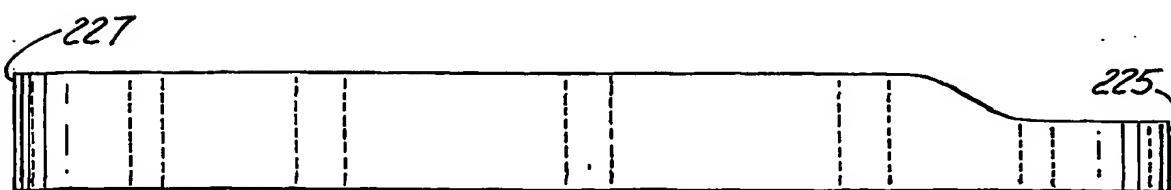
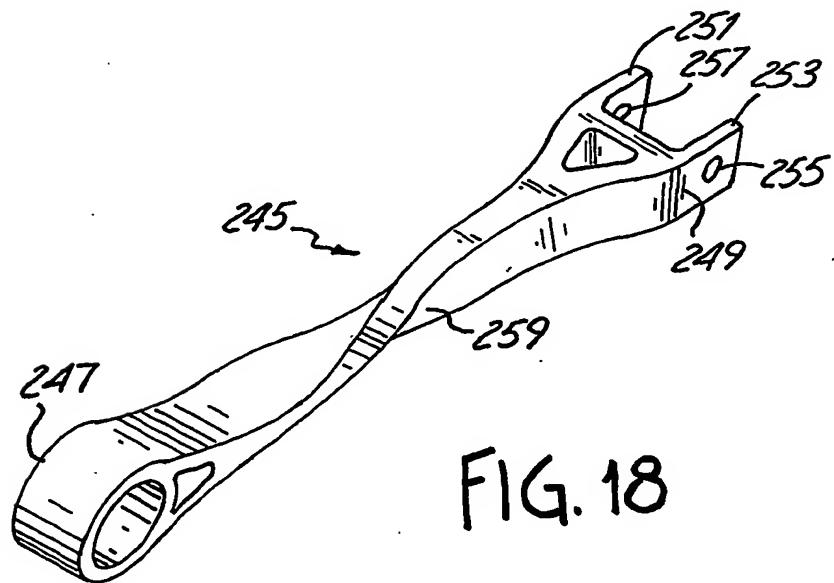
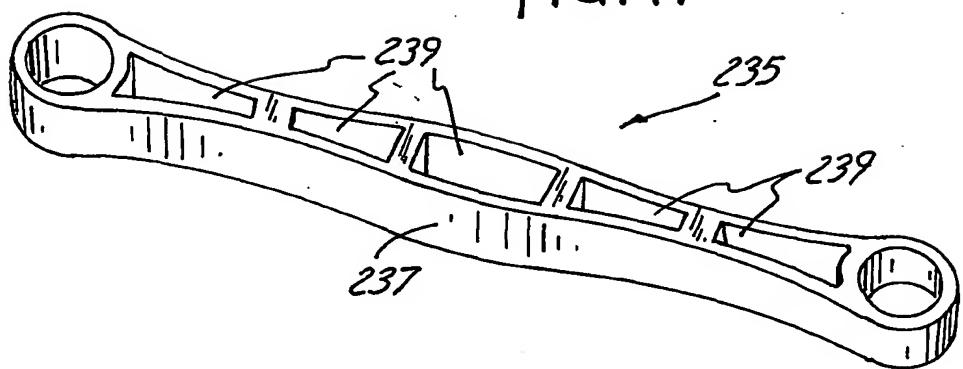


FIG. 17



## INTERNATIONAL SEARCH REPORT

Inte	rial Application No
PCT/US 01/27546	

A. CLASSIFICATION OF SUBJECT MATTER					
IPC 7	B23K20/12	B60G3/06	B60G7/00	B23P13/04	B62D21/15

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 B23K B60G B23P B62D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

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## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 2000, no. 03, 30 March 2000 (2000-03-30) -& JP 11 347754 A (SUMITOMO LIGHT METAL IND LTD), 21 December 1999 (1999-12-21) abstract	1,2,4-6
Y A	---	3 7-17
X	PATENT ABSTRACTS OF JAPAN vol. 1998, no. 06, 30 April 1998 (1998-04-30) -& JP 10 035235 A (SHOWA ALUM CORP), 10 February 1998 (1998-02-10) abstract	7-10, 13-17
Y A	---	3,11,12 1,2,4-6
		-/-

Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

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Date of the actual completion of the International search

7 February 2002

Date of mailing of the International search report

13/02/2002

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Haegeman, M

## INTERNATIONAL SEARCH REPORT

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PCT/US 01/27546

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	PATENT ABSTRACTS OF JAPAN vol. 1999, no. 09, 30 July 1999 (1999-07-30) -& JP 11 101286 A (TOKAI RUBBER IND LTD; SHOWA ALUM CORP), 13 April 1999 (1999-04-13) abstract ----	11,12
X	PATENT ABSTRACTS OF JAPAN vol. 1999, no. 08, 30 June 1999 (1999-06-30) -& JP 11 058036 A (HITACHI LTD), 2 March 1999 (1999-03-02) abstract ----	1,2,7,8, 10-14
X	PATENT ABSTRACTS OF JAPAN vol. 2000, no. 05, 14 September 2000 (2000-09-14) -& JP 2000 061663 A (SUMITOMO LIGHT METAL IND LTD), 29 February 2000 (2000-02-29) abstract ----	1,2

**INTERNATIONAL SEARCH REPORT**

Information on patent family members

Inte      il Application No  
PCT/US 01/27546

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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JP 10035235	A 10-02-1998	NONE	
JP 11101286	A 13-04-1999	NONE	
JP 11058036	A 02-03-1999	NONE	
JP 2000061663	A 29-02-2000	NONE	